MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2015/2016

EPH7016 – FUNDAMENTALS OF MODERN OPTICS

(All sections / Groups)

03 OCTOBER 2015
2.30 p.m - 5.30 p.m
(3 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 6 pages with 4 Questions only.

2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) Use small angle approximation to derive *Lens' Maker* equation.

[6 marks]

(b) Describe the optical phenomenon that allows light to travel inside an optical fiber. Support your answer with a suitable diagram and relevant formula.

[6 marks]

(c) A 20 mm tall object is located 80mm in front of a +50 mm focal length thin lens. A concave spherical mirror, with a radius of curvature of 25 mm is located 75 mm from the lens on the other side of the lens. Find the position, size of the image and characteristics of the image.

[13 marks]

Question 2

(a) Use of *Vector Wave* equation to derive the interference equation.

[6 marks]

(b) As an optical engineer, you are required to design an interferometer that can measure the flatness of a bare silicon wafer (180 mm diameter) up to 500 nm uncertainty in room condition. Describe your works with an aid of a diagram.

(i) State your choice and justification of your choice.

[4 marks]

(ii) With the aid of a diagram, identify the components used in your system.

[5 marks]

(iii) Using the results from Q2(a), derive the displacement equation of the system. Suggest the specification of the component used in the system.

[10 marks]

Continued .....

Question 3

(a) What is meant by polarized and unpolarized light? Give an example of both.

[6 marks]

(b) Describe linear, circular and elliptical polarizations by using appropriate electric field equations.

[6 marks]

(c) The critical angle of a certain transparent material in air is found to be 33°. What are its *Brewster's* angles for both external and internal reflections?

[6 marks]

(d) Light linearly polarized with a horizontal transmission axis is sent through another linear polarizer with transmission axis at 45° and then through a quarter wave plate with slow axis horizontal. Use the Jones matrix technique to determine and describe the product light.

[7 marks]

Question 4

(a) Describe the light propagation in an absorbing medium that will lead to the formulation of *Beer's* law.

[8 marks]

(b) Using this principle in Q3(a), reconstruct the cross section plane of a semi-absorbing medium by using the projection slice theorem and *Radon Transform*. State your assumptions.

[17 marks]

Continued .....

Physical Constants and Units

Constant	Symbol	Value (mks units)
Speed of light in vacuum	C	3×10^{8} m/s
Electron charge	Q	1.602×10^{-19} C
Boltzmann's constant	k_B	1.38×10^{-23} J/K
Permittivity of free space	ε_0	8.8542×10^{-12} F/m
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ N/A^2
Electron volt	eV	1 eV = 1.602×10^{-19} J
Planck's constant	h	6.626×10^{-34} J·s

- Free space $$\mathfrak{T} = \begin{bmatrix} 1 & \frac{d}{n} \\ 0 & 1 \end{bmatrix}$$
- Refraction at a planar boundary $$\mathfrak{R} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$
- Refraction at a spherical boundary $$\mathfrak{R} = \begin{bmatrix} 1 & 0 \\ \frac{-(n_2 - n_1)}{R} & 1 \end{bmatrix}$$
- Transmission through thin lens $$\mathfrak{T} = \begin{bmatrix} 1 & 0 \\ -\frac{1}{f} & 1 \end{bmatrix}$$
- Reflection from a planar mirror $$\mathfrak{R} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$
- Reflection from a spherical mirror $$\mathfrak{R} = \begin{bmatrix} 1 & 0 \\ \frac{2}{R} & 1 \end{bmatrix}$$

Continued .....

Summary of Jones Matrices

I. Linear polarizers

TA horizontal $\begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix}$ TA vertical $\begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix}$ TA at 45° to horizontal $\frac{1}{2}\begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix}$

II. Phase retarders

General $\begin{bmatrix} e^{i\varepsilon_x} & 0 \\ 0 & e^{i\varepsilon_y} \end{bmatrix}$

QWP, SA vertical $e^{-i\pi/4}\begin{bmatrix} 1 & 0 \\ 0 & i \end{bmatrix}$ QWP, SA horizontal $e^{i\pi/4}\begin{bmatrix} 1 & 0 \\ 0 & -i \end{bmatrix}$

HWP, SA vertical $e^{-i\pi/2}\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$ HWP, SA horizontal $e^{i\pi/2}\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$

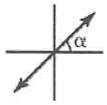
III. Rotator

Rotator $(\theta \rightarrow \theta + \beta)$ $\begin{bmatrix} \cos\beta & -\sin\beta \\ \sin\beta & \cos\beta \end{bmatrix}$

Continued .....

Summary of Jones Vectors

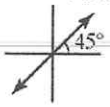
I. Linear Polarization ($\Delta\varphi = m\pi$)

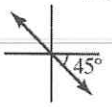
General: 

$$\tilde{\mathbf{E}}_0 = \begin{bmatrix} \cos\alpha \\ \sin\alpha \end{bmatrix}$$

Vertical: $\tilde{\mathbf{E}}_0 = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$

Horizontal: $\tilde{\mathbf{E}}_0 = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$

At + 45°: $\tilde{\mathbf{E}}_0 = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 \\ 1 \end{bmatrix}$ 

At −45°: $\tilde{\mathbf{E}}_0 = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 \\ -1 \end{bmatrix}$ 

II. Circular Polarization $\left(\Delta\phi = \frac{\pi}{2}\right)$

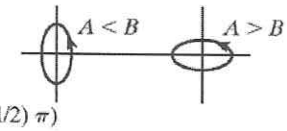
Left:

$$\tilde{\mathbf{E}}_0 = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 \\ i \end{bmatrix}$$

Right:

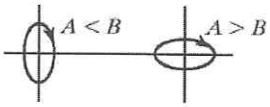
$$\tilde{\mathbf{E}}_0 = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 \\ -i \end{bmatrix}$$

III. Elliptical Polarization

Left: 

$$\tilde{\mathbf{E}}_0 = \frac{1}{\sqrt{A^2 + B^2}}\begin{bmatrix} A \\ iB \end{bmatrix} \quad A > 0, B > 0$$

$(\Delta\phi = (m + 1/2)\,\pi)$

Right: 

$$\tilde{\mathbf{E}}_0 = \frac{1}{\sqrt{A^2 + B^2}}\begin{bmatrix} A \\ -iB \end{bmatrix} \quad A > 0, B > 0$$

Left:

$$\tilde{\mathbf{E}}_0 = \frac{1}{\sqrt{A^2 + B^2 + C^2}}\begin{bmatrix} A \\ B + iC \end{bmatrix} \quad A > 0, C > 0$$

$\left(\Delta\phi \neq \begin{cases} m\pi \\ (m + 1/2)\pi \end{cases}\right)$

Right:

$$\tilde{\mathbf{E}}_0 = \frac{1}{\sqrt{A^2 + B^2 + C^2}}\begin{bmatrix} A \\ B - iC \end{bmatrix} \quad A > 0, C > 0$$

End of Page